Met.O.880
METEOROLOGICAL OFFICE

the meteorological magazine

MAY 1975 No 1234 Vol 104
Her Majesty's Stationery Office

METEOROLOGICAL OFFICE Met.O.880

THE METEOROLOGICAL MAGAZINE

Vol. 104, No. 1234, May 1975

551.507.362.2:551.509.313

AN EXPERIMENT TO DETERMINE THE VALUE OF SATELLITE INFRA-RED SPECTROMETER (SIRS) DATA IN NUMERICAL FORECASTING

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Summary. An experiment was carried out in the Meteorological Office in March 1974 to evaluate SIRS as an operational source of data. As a result SIRS data are now available for use in the operational forecast, but are subject to scrutiny by the upper-air forecaster.

Introduction. In 1973 the United States of America announced that during the 12 months from June 1973 its weather ships would be withdrawn one by one from service at Ocean Weather Stations (OWS) 'B', 'C', 'D' and 'E' in the western Atlantic, and that the experimental Satellite Infra-red Spectrometer (SIRS) soundings would be transmitted operationally. It was therefore necessary to evaluate the SIRS data[1] (sometimes described as Vertical Temperature Profile Radiometer (VTPR) data) as an operational source of data.

An experiment was set up consisting of an additional forecast run in parallel with the operational forecast. In the experiment, satellite data were allowed to supplement conventional data in the numerical forecast suite. Use was made of data from 00 GMT on 7 March 1974 to 00 GMT on 15 March 1974.

The model used both operationally and for the experiment was the Bushby–Timpson 10-level primitive-equation model[2] in its two forms:

(a) coarse-mesh over an octagonal area centred on the North Pole and tangential to about 15°N on a polar stereographic projection ('the octagon');

(b) fine-mesh over a rectangular area (on the same projection) covering the North Atlantic and Europe ('the rectangle').

Both forms used the technique of quadric-fitting at grid points to provide objective analyses.[3,4]

Organization of the experiments

(a) *General remarks.* In spite of the large amount of computer time involved in running an experimental forecast suite for each 12-hour datum time over a period, the experiment was run in 'real time' to avoid problems of recovering data from an archive, and to enable more realistic intervention to be effected (see below).

The programs that provided analyses of geopotential height and humidity over the octagon and rectangle were made flexible, so that the choice of data to be used was controlled externally. Thus both program suites automatically used the same method of analysis and were therefore directly comparable. However, some effort was required in advance to ensure that the octagon and rectangle versions of the height analysis were compatible, particularly in the method of incorporating SIRS data.

Each analysis program needs a 'background field', which is a first guess at the analysed field. It is normally a 12-hour forecast from the previous update run (see below). In the experimental suite it was necessary to use the same background fields of height and humidity as in the operational suite for the first datum time, but thereafter each suite produced its own background fields. Thus there was a 'run-up' period of about two days during which the effect of satellite data was allowed to become fully established in the experiment.

(b) *Intervention.* In the operational suite, incoming data are read from paper tape, and at fairly frequent times of the day a 'data bank' is updated with the most recently received data. Before the height and humidity analyses are made, a set of 'Basic Analysis Data Sets' (BADS) is compiled from the current data bank for both octagon and rectangle. In order to justify comparison of the suites, it was necessary to arrange identical cut-off times for the data. This requirement was satisfied most readily by starting the experiment from the set of operational BADS, since decisions about inclusion or exclusion of types of data could be made during the height and humidity analyses.

Such an arrangement means that all intervention except the addition of artificial observations (also known as 'bogus' observations) will have been effective by the time the BADS are produced. Therefore any difference of intervention between the suites must be carried out in the form of bogus observations.

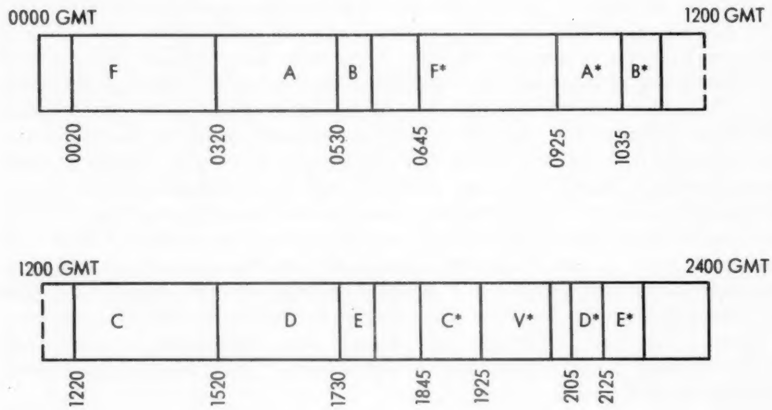
For the period of the experiment an extra roster of forecasters was on duty in the Central Forecasting Office (CFO) at Bracknell, to provide bogus intervention appropriate to the experiment. The intervener could use as much SIRS information as he could acquire, whether or not it had been included in the BADS. He was provided with machine-plotted charts appropriate to the experiment, and of course the computer output from the experiment itself. The operational forecaster was not allowed access to any SIRS information.

(c) *The program suites.* In the remainder of this paper, the adjective 'main' refers to runs with a data cut-off time of 0300 or 1515 GMT, whereas 'update' refers to runs with a cut-off time of 1200 or 0000 GMT. The purpose of the update run is to introduce into the model all the appropriate data that have been received since the main-run cut-off time. The influence of these data is indirect, since the forecast is taken to 12 hours only, and is used to provide background fields for the height and humidity analyses of the next main run.

In order to reduce demand on the computer resources for the experiments, full 72-hour (octagon) and 36-hour (rectangle) main forecasts were made using

only midnight data. However, a complete cycle of main and update runs was necessary for octagon and rectangle, but the runs based on midday data were considerably shortened, and the requirement for output was considerably less than in the operational suite. The arrangement of the running of the suites in real time is depicted in Figure 1. The timing of the runs was chosen to enable the forecaster to intervene under pressure similar to that experienced on the operational bench, although in practice that pressure was difficult to achieve.

(d) *Assessment of results.* The forecasts were assessed both subjectively and objectively. The objective assessment made use of a verification scheme essentially similar to that used in the octagon operational suites, although special



Definitions of A–F, A*–F* and V*

Run	Operational	Experimental
Midnight main octagon	A	A*
Midnight main rectangle	B	B*
Midnight update octagon and rectangle	C	C*
Midday main octagon	D	D*
Midday main rectangle	E	E*
Midday update octagon and rectangle	F	F*
Verification and preservation of results		V*

FIGURE 1—ARRANGEMENT OF RUNS IN REAL TIME DURING THE EXPERIMENT

provision had to be made for use over a limited period. Forecasts made during the 'run-up' period were not verified. Furthermore, in order to verify the forecasts from the final datum time, special programs were run for three days from the end of the experiment (the 'run-down' period). Also included were programs to verify the operational forecasts over the same period, for comparison with the experiments.

Objective verification of rectangle rainfall forecasts will be described in a later paragraph.

Synoptic situation 9–15 March 1974. The first part of the period of the experiment began with high pressure over Scandinavia with a ridge extending over the British Isles, lower pressure over northern France, and a deep depression in the west Atlantic between Newfoundland and Greenland. Small lows moved round the main depression and some broke away and ran into northern France and southern Britain. These were fairly shallow features with small amounts of rain and they dissipated as they moved towards the main high. A similar pattern was reflected in the upper air with troughs moving round the Atlantic low and ridges building between them. A cut-off 500-mb low remained over the British Isles until 14 March. The region of high pressure moved slowly eastwards, leaving a cut-off high near Iceland. On 14 March the block broke down and a secondary low running round the old west-Atlantic low became dominant, deepened and ran forward across the British Isles with associated belts of rain. This was associated with the eastward extension to the south of Iceland of an upper trough from the old west-Atlantic low and the return of westerly flow over the southern part of the British Isles. Figure 2 is reproduced from *Weather Log* for March 1974 (published by the Royal Meteorological Society) and shows the sequence of midday hand-drawn analyses for the period.

Subjective assessment. The assessment began with forecasts based on data for 00 GMT, 9 March 1974, that is to say, after the run-up period. The area considered in the subjective assessment was centred on the British Isles and included parts of western Europe and the eastern Atlantic. The rectangle forecasts of 500-mb height, surface pressure and rate of rainfall were assessed at 12-hourly intervals and the octagon forecasts of surface pressure and 500-mb height were assessed at 24-hourly intervals. In addition the surface-pressure and 500-mb analyses were assessed for each area. A combined mark was given for each forecast and a separate mark was given for the surface and 500-mb analyses according to the following scale:

A Experimental run (including the SIRS data) significantly better than the operational run.
B Experimental run better than the operational run.
C Experimental run and operational run equally good.
D Experimental run worse than the operational run.
E Experimental run significantly worse than the operational run.

('Significant' in categories 'A' and 'E' implies that a forecast issued on the basis of the computer prognosis would be different. Categories 'B' and 'D' indicate that some differences were found in the computer prognoses but that these would not have affected an issued forecast.) In addition there was a

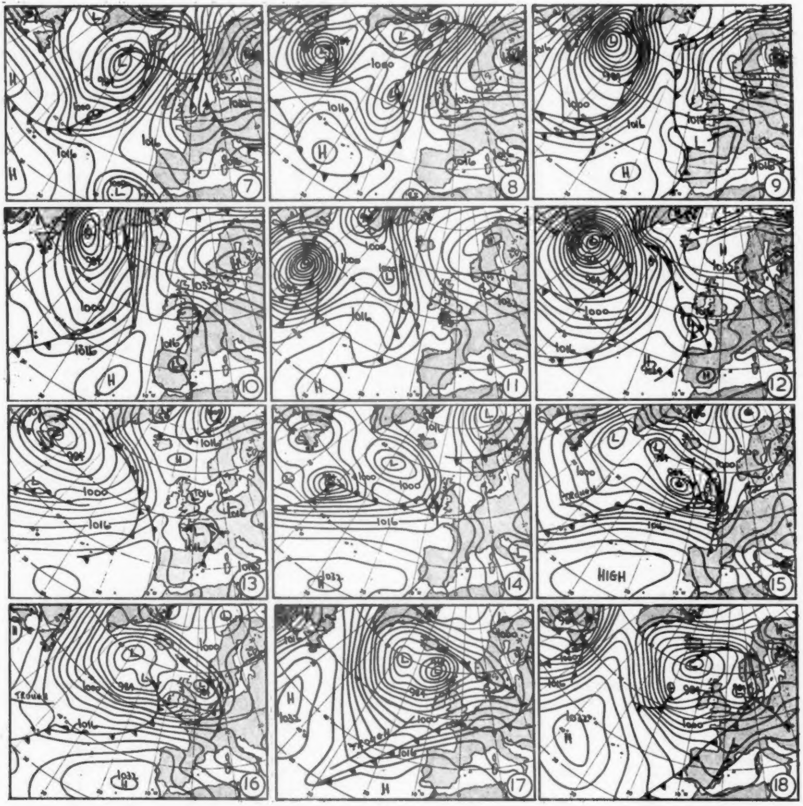


FIGURE 2—DAILY WEATHER MAPS FOR 12 GMT, MARCH 1974
Dates are ringed at the lower right-hand corner of each map.
Mean-sea-level isobars are drawn at intervals of 4 millibars.

category 'X' used for analyses only, which implied that the charts were different but that owing to the lack of conventional data it was impossible to decide which was the better. The results of the subjective assessment for individual days are shown in Table I and a summary is shown in Table II.

As can be seen from Table II there were no 'A' or 'E' marks. This means that on no occasion would the forecast of weather issued for the British Isles have been affected by the inclusion of satellite data. For most comparisons, especially of forecasts for a period of more than 24 hours, the predictions were closer to each other than to the actual situation. In particular, as indicated by the annotation in Table I, none of the forecasts predicted the change of type to westerly conditions which occurred on 14 March. It is interesting to note that the octagon forecast based on 00 GMT, 14 March gave the largest reduction in root-mean-square 500-mb height error when SIRS data were included (see Figure 3). The forecasts were assessed subjectively as equally good because although they were different from each other they were equally misleading.

TABLE I(a)—RESULTS OF SUBJECTIVE ASSESSMENT—OCTAGON

Data time 00 GMT March 1974	Analysis Surface pressure	Analysis 500-mb	$T + 24$	$T + 48$	$T + 72$	Number of SIRS in analysis area
9th	D*	C	D	D	B	43
10th	C	C	B	B	B	53
11th	C	B	B	C	C	102
12th	B*	C	B	B	C†	30
13th	C	C	C	B	B	16
14th	C	X	C†	C†	C†	120
15th	C	C	D	C	C	62

TABLE I(b)—RESULTS OF SUBJECTIVE ASSESSMENT—RECTANGLE

Data time 00 GMT March 1974	Analysis Surface pressure	Analysis 500-mb	$T + 12$	$T + 24$	$T + 36$	Number of SIRS in analysis area
9th	D*	C	B	C	C	2
10th	C	C	C	C	B	15
11th	C	C	C	B	C	16
12th	C	X	B	B	C	14
13th	C	C	C	C	C	5
14th	C	X	B	B†	C†	34
15th	B	D	D	D	C	11

* Due to pre-intervention.
† Both forecasts poor.
For explanation of letters see page 128.

TABLE II—SUMMARY OF THE RESULTS OF THE SUBJECTIVE ASSESSMENT SHOWING THE NUMBERS OF ASSESSMENTS IN EACH CATEGORY DERIVED FROM TABLE I

(a) Octagon

Category	Analysis Surface	Analysis 500-mb	$T + 24$	$T + 48$	$T + 72$	Total from forecasts	Percentage of forecasts
A	0	0	0	0	0	0	0
B	1	1	3	3	3	9	43
C	5	5	2	3	4	9	43
D	1	0	2	1	0	3	14
E	0	0	0	0	0	0	0
X	0	1					

(b) Rectangle

Category	Analysis Surface	Analysis 500-mb	$T + 12$	$T + 24$	$T + 36$	Total from forecasts	Percentage of forecasts
A	0	0	0	0	0	0	0
B	1	0	3	3	1	7	33
C	5	4	3	3	6	12	57
D	1	1	1	1	0	2	10
E	0	0	0	0	0	0	0
X	0	2					

For explanation of letters see page 128.

Considering the above points and bearing in mind that the results on some occasions were influenced by different 'pre-intervention' (that is, intervention before the main-run analysis, see Table I) it is nevertheless true that on the whole the inclusion of satellite data was beneficial. This is particularly noticeable for the octagon forecasts which were better for 43 per cent of forecasts when satellite data were included. On many occasions when a 'C' marking was given there was, in fact, a slight improvement when SIRS data were included, whereas the reverse was true on very few occasions.

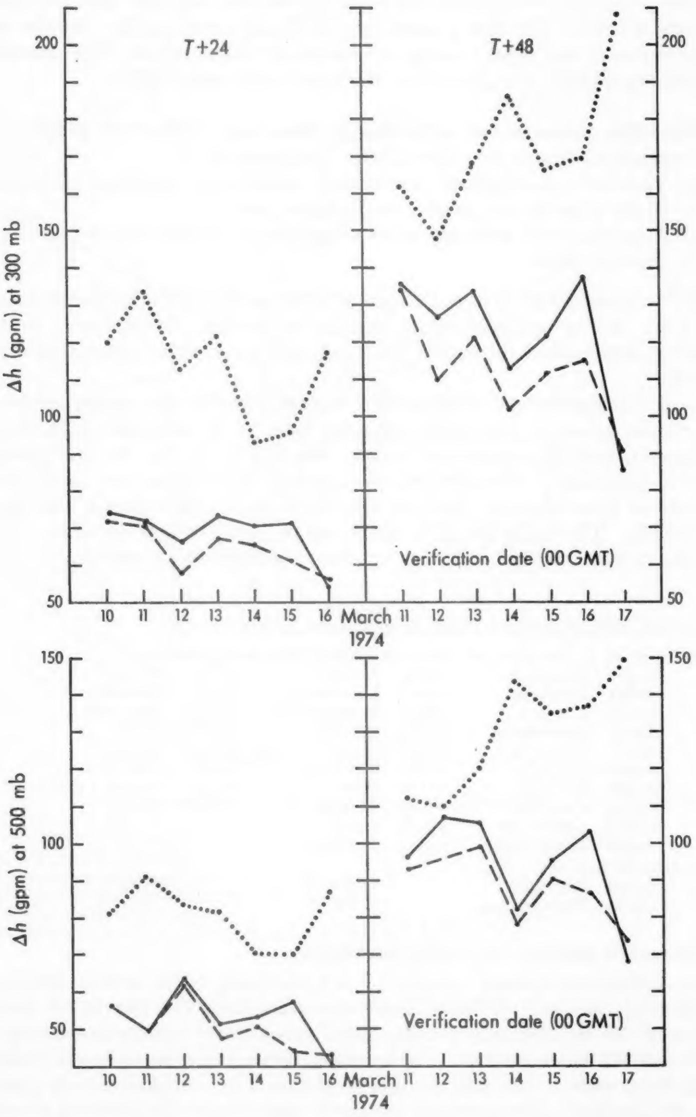


FIGURE 3—ROOT-MEAN-SQUARE DIFFERENCES, Δh, BETWEEN FORECAST AND OPERATIONAL UPDATE-RUN ANALYSED HEIGHTS FOR 24-HOUR AND 48-HOUR FORECASTS AT EACH 00 GMT VERIFICATION TIME

Top: 300 mb Bottom: 500 mb

●——● operational ●- - -● experimental ●· · ·● persistence

There were only two occasions when the forecast without satellite data was marked as better. The first was 00 GMT, 9 March 1974. In this case the operational forecast was better owing to better pre-intervention. The second was 00 GMT, 15 March 1974, which is discussed separately below.

Objective assessment of octagon forecast. Objective verification of the experiment made use of two basic comparisons:

(a) Forecast fields against operational update-run analysed or initialized fields appropriate to the verification time.

(b) Forecast fields against values observed at various stations at the verification time.

The 'forecast fields' referred to are of three kinds: one from the experiment, one from the operational suite, and, as a control, 'persistence', in which observed, analysed or initialized values are maintained throughout the forecast period.

In the comparison of forecast and analysed fields, the region used was a rectangular array of 560 points covering most of Europe, the Atlantic, most of Canada, and the north-east U.S.A. (see Figure 4). In the comparison of forecast fields with observations, two groups of stations are used: one of 28 stations in north-west Europe, the other of six mid-Atlantic stations (see Table III). The latter group is clearly more prone to influence from a single station, so that caution is necessary when considering its statistics.

TABLE III—OBSERVATIONS USED IN OCTAGON VERIFICATION

(a) 28 Stations in Europe and their international station numbers

01415	Stavanger	03953	Valentia	07645	Nîmes
02084	Göteborg	06011	Thorshavn	10035	Schleswig
03005	Lerwick	06181	København	10338	Hannover
03026	Stornoway	06260	De Bilt	10384	Berlin
03170	Shanwell	06447	Uccle	10739	Stuttgart
03322	Aughton	06610	Payerne	10866	München
03496	Hemsby	07110	Brest	12330	Poznań-Lawica
03774	Crawley	07145	Trappes	16080	Milano
03808	Camborne	07480	Lyon		
03920	Long Kesh	07510	Bordeaux		

(b) 6 Atlantic Stations

04018	Keflavík	OWS 'B'	OWS 'J'
04270	Narssarssuaq	OWS 'I'	OWS 'K'

Forecasts against analyses (octagon)

(a) *Accumulated statistics.* Table IV is a summary of the accumulated statistics for 12-, 24- and 36-hour height forecasts from the two suites over the period of the experiment, excluding the run-up and run-down periods. The effect of SIRS observations is in general a beneficial one, according to Table IV, at all levels except 100 mb. At this level raw SIRS thickness data (adjusted only by addition of a 1000-mb analysed value) have an inherent roughness which is reduced at lower levels by a correction based on the 100-mb random error.[3]

(b) *Daily statistics—height errors.* Figures 5(a) and 5(b) represent comparisons of the progress of each individual forecast at 200 mb and 500 mb in terms of root-mean-square (r.m.s.) height differences between the forecast and the operational-update analysis at the verification time. If forecast periods of less

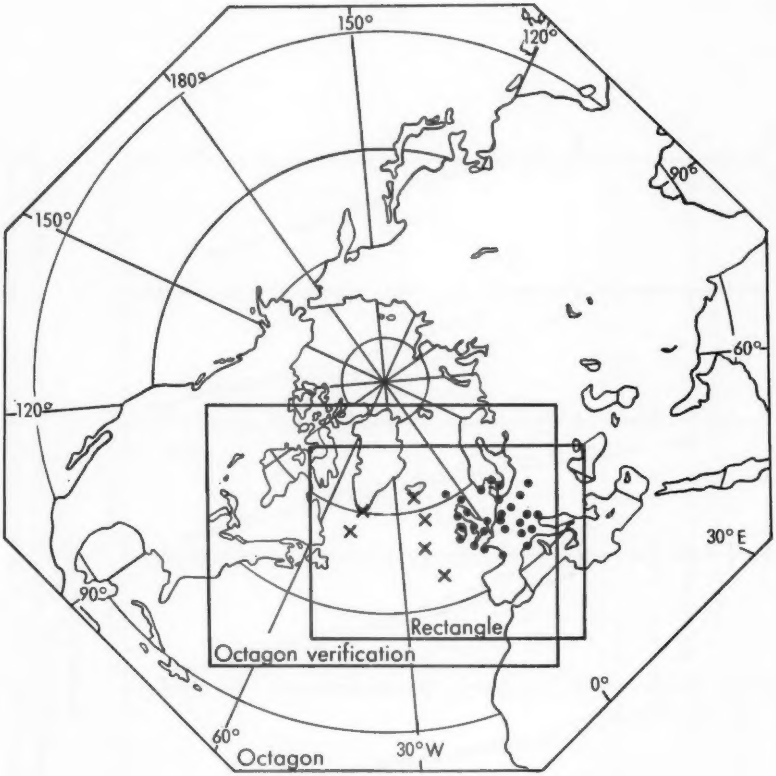


FIGURE 4—10-LEVEL MODEL REGIONS

Octagon 3037 grid points
Rectangle 3072 grid points
Verification region 560 grid points
● 28 upper-air stations (Europe)
× 6 upper-air stations (Atlantic)
Partial latitude circles are shown at 20°, 40°, 60° and 80°N.

than 24 hours are ignored for the present it can be seen that all the experimental forecasts have lower r.m.s. height differences than the corresponding operational forecasts, with the exception of the last. In the earlier part of each of the 500-mb forecasts, the experimental one has larger errors (except for one day), whereas at 200 mb the reverse is the case, with the final day again being an exception.

Figure 3 compares equal-period forecasts of height from the experiment, the operational suite and persistence, on a daily basis for two levels. Again they show that on every occasion except the last the experimental forecast was slightly less in error than the operational forecast and that both were considerably better than persistence.

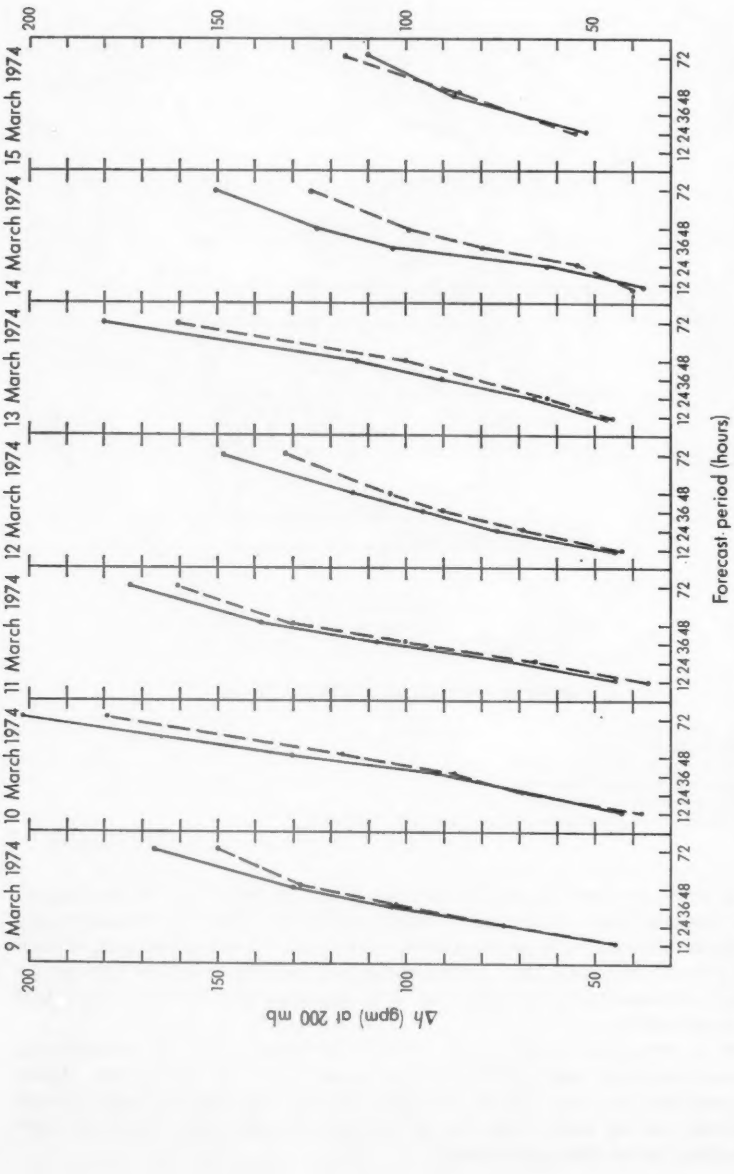


FIGURE 5(a)—ROOT-MEAN-SQUARE DIFFERENCES, Δh, BETWEEN FORECAST HEIGHTS AND OPERATIONAL UPDATE-RUN ANALYSED HEIGHTS FROM 00 GMT DATA, FOR INCREASING FORECAST PERIODS (200 mb)

●——● operational ●- - -● experimental

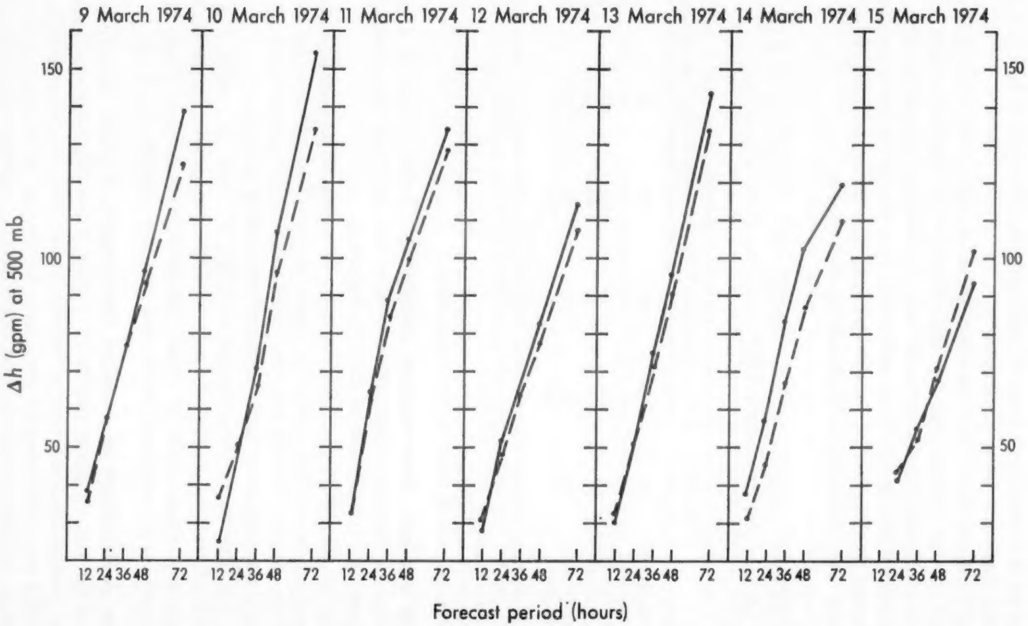


FIGURE 5(b)—ROOT-MEAN-SQUARE DIFFERENCES, Δh, BETWEEN FORECAST HEIGHTS AND OPERATIONAL UPDATE-RUN ANALYSED HEIGHTS FROM 00 GMT DATA, FOR INCREASING FORECAST PERIODS (500 mb)

●——● operational ●- - -● experimental

(c) *Daily statistics—wind errors.* Figures 6(a), 6(b) and 6(c) represent comparisons of persistence, operational and experimental mean vector-wind errors for 24-, 48- and 72-hour forecasts respectively at two levels. The values plotted are of the mean vector departure of the forecast wind from the operational update-run initialized wind at verification time. An organizational error caused the statistics for a verification time of midnight on the 15th to be invalid, so these statistics have not been presented.

In general Figure 6 shows that the experiment usually produces a very slight improvement on the operational forecast. Figure 6(c) shows further that in the relatively static synoptic situation at the beginning of the period a 72-hour persistence forecast was better than either the operational or the experimental 72-hour forecast. It is probably unwise to make any more-detailed inferences, in view of the wide variability displayed by the curves.

TABLE IV—OCTAGON 10-LEVEL MODEL VERIFICATION, 00 GMT ON 9 MARCH TO 00 GMT ON 15 MARCH 1974 (ACCUMULATED STATISTICS)

	Forecast	Number of cases*	1000 mb	500 mb	300 mb	200 mb	100 mb
			Root-mean-square height differences in geopotential metres between forecast and objective analysis†				
$T + 12$	Experimental†	12	25	30	40	40	51
	Operational†	12	25	30	39	40	49
$T + 24$	Experimental	6	43	52	65	66	89
	Operational	11	45	55	69	70	89
$T + 36$	Experimental	5	59	73	87	92	127
	Operational	10	62	76	97	97	123

* Experimental 24- and 36-hour forecasts are available only for midnight data, whereas the midday forecasts are included in the operational statistics and also in the 12-hour experimental statistics.

† All $T + 12$ forecast statistics are based on update runs. The update-run objective analysis at the verification time is used for the comparison.

Forecasts against observations (octagon). Table III(a) is a list of the 28 European stations whose observations are used in the comparison, and their positions are plotted as dots in Figure 4.

As a guide to the effect of SIRS data on forecasts of jet speed, Figure 7 shows a comparison of daily 300-mb r.m.s. vector-wind errors. The experimental and operational curves are very similar for both 24-hour and 48-hour forecasts, with the exception once again of the end of period.

Since the withdrawal of observations at OWS 'C' and 'D', there is a very poor network of stations available for a similar comparison in the Atlantic area. Such a comparison was in fact made, using the six stations of Table III(b), but the results were unrepresentative and are not reproduced here.

Objective verification of rainfall (rectangle). Rainfall accumulations were verified for the 14 areas shown in Figure 8 for the forecasts based on data for the period from 00 GMT, 9 March to 00 GMT, 15 March 1974. An average rainfall was calculated for each area for the 12- to 24-hour and 24- to 36-hour periods of both the operational and experimental forecasts. These were verified against actual average values obtained for the same areas from rainfall data from synoptic stations.

The results, illustrated in Tables V and VI, show very little difference between the two forecasts. Certainly they show that forecasts including satellite data were no worse than those without. Table V shows the accuracy of the forecasts

in distinguishing between wet and dry periods. For accumulations over the 24-hour period from 12 to 36 hours the two forecasts were identical; for the two 12-hour periods 12 to 24 and 24 to 36 combined, the forecasts including satellite data were marginally better. This indicates that the experimental forecasts were slightly better at timing the rain than the operational forecasts, but the differences are insignificant especially in view of the errors in deriving areal mean values from relatively sparse actual rainfall data. Table VI compares the sum of the forecast values for each area for both forecasts with the sum of the actual mean values. This comparison shows that except for the forecast beginning at 00 GMT on 15 March 1974 there were no significant differences in the total rain predicted by the two forecasts, the forecasts including satellite data being marginally better. For 00 GMT on 15 March, there was a significant decrease in the amount of rain predicted when satellite data were included. The experimental forecast appears to be the better in this case.

It is unfortunate that there was only one occasion (15 March) during the experiment when there was a belt of widespread frontal rain in the verification area and therefore the results do not give any reliable information about the effect of satellite data on forecasting similar frontal situations with widespread moderate or heavy rain.

TABLE V—2 × 2 CONTINGENCY TABLE FOR WET AND DRY PERIODS, COMBINING ALL THE AREAS DEPICTED IN FIGURE 8

(a) All 12-hour periods $T + 12$ to $T + 24$ and $T + 24$ to $T + 36$

		Operational				Experimental	
		DRY	WET			DRY	WET
Actual	DRY	57	16	Actual	DRY	58	15
	WET	40	83		WET	39	84

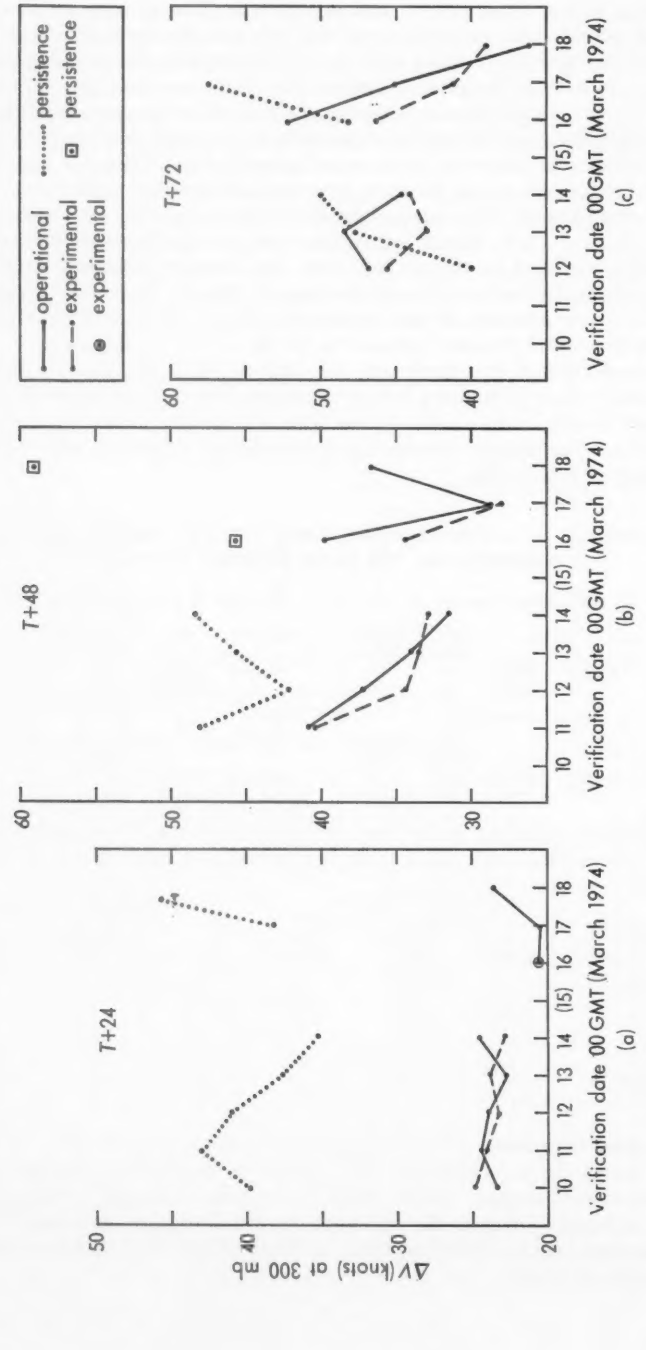
(b) All 24-hour periods $T + 12$ to $T + 36$

		Operational				Experimental	
		DRY	WET			DRY	WET
Actual	DRY	23	6	Actual	DRY	23	6
	WET	21	48		WET	21	48

TABLE VI—DAILY TOTALS OF THE MEAN VALUES OF ACCUMULATED RAIN (IN MILLIMETRES) IN EACH OF THE 14 AREAS SHOWN IN FIGURE 8

Data time 00 GMT March 1974	Verification period $T + 12$ to $T + 24$ Actual	Without SIRS	With SIRS	Verification period $T + 24$ to $T + 36$ Actual	Without SIRS	With SIRS
9th	3	3	3	8	2	2
10th	12	4	5	9	4	4
11th	8	7	7	9	7	8
12th	15	6	6	15	5	6
13th	9	6	6	8	10	8
14th	14	9	9	28	9	10
15th	24	41	30	17	26	18

The last forecast. The octagon forecast from a datum time of 00 GMT on 15 March 1974 (which was the last datum time of the experiment) has been mentioned several times as being exceptional. The subjective assessment of the rectangle forecasts for the same datum time also indicated that the experimental forecast was worse up to 24 hours (Table I(b)). Some explanation is therefore required.



operational
experimental
experimental
persistence
persistence
T+24
T+48
T+72
ΔV (knots) at 300 mb
Verification date 00GMT (March 1974)
(a)
(b)
(c)

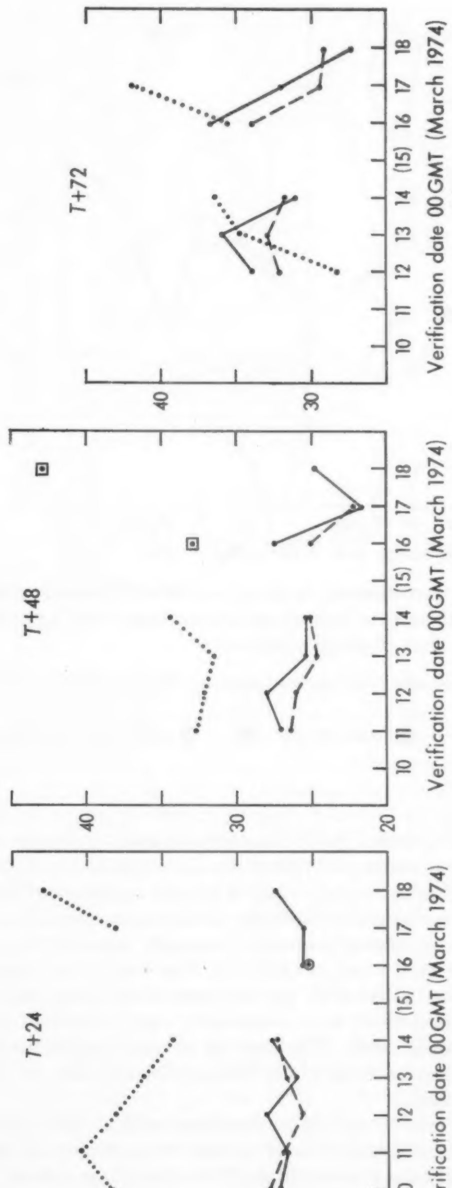


FIGURE 6—MEAN VECTOR WIND DIFFERENCES, ΔV, BETWEEN FORECASTS AND OPERATIONAL UPDATE-RUN ANALYSES AT EACH 00 GMT VERIFICATION TIME AT 300 mb AND 500 mb

(a) 24-hour forecast (b) 48-hour forecast (c) 72-hour forecast

An organizational error invalidated the statistics for a verification time of 00 GMT on 15 March and also invalidated the statistics for persistence forecasts from that time.

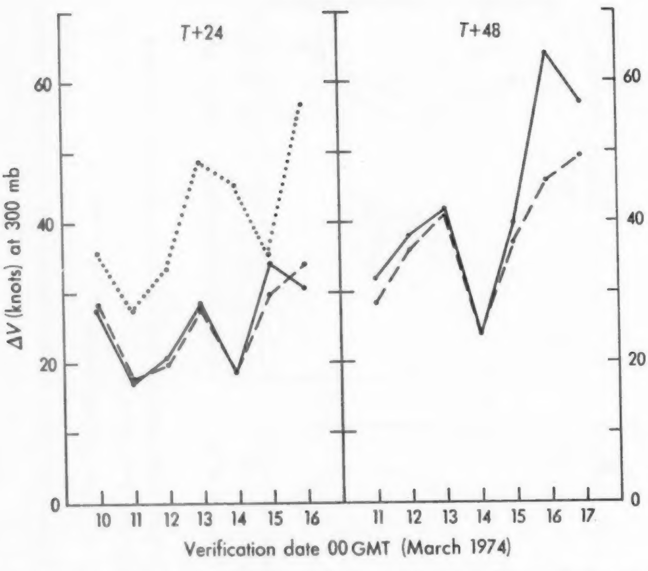


FIGURE 7—MEAN VECTOR WIND DIFFERENCES, ΔV, BETWEEN 300-mb FORECASTS AND OBSERVATIONS AT EACH 00 GMT VERIFICATION TIME FOR 24-HOUR AND 48-HOUR FORECASTS

The 28 European stations whose observations were used for this comparison are listed in Table III(a).

●——● operational ●- - -● experimental ●. . .● persistence (24-hour only)

In spite of a better background field, the experimental rectangle 500-mb analysis was poorer, owing to erroneous rejection of 400-mb and 500-mb wind observations from OWS 'I' which were retained by the operational rectangle analysis. (These winds were rejected by both the octagon analyses.) It is worth noting at this point that *both* rectangle analyses wrongly rejected the 300-mb wind and 1000–500-mb thermal wind at OWS 'I'. The wind rejection scheme (which compares an observed wind with the corresponding interpolated wind from an analysis of unchecked data) can occasionally reject a crucial observation, as it appears to have done here. (The method of applying quality-control checks to wind observations is under study in connection with the orthogonal-polynomial method of analysis.)

On the 14th and 15th the blocking anticyclone which had dominated northern Europe declined, allowing a brief period of westerlies to develop. Figures 3 and 7 show a tendency towards peaks in the error curves for the penultimate octagon case, which could therefore be rated as a relatively poor forecast, as might be expected when a blocking situation suddenly subsides. However, it is for this penultimate case that the improvement in the forecast due to the inclusion of SIRS data in the analysis is greatest.

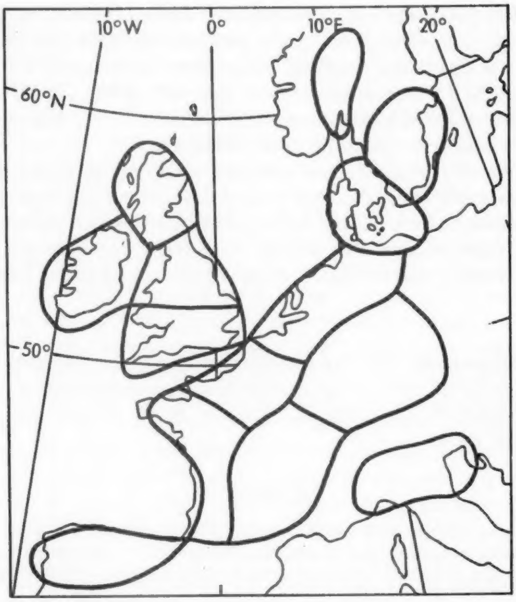


FIGURE 8—AREAS OVER WHICH RAINFALL WAS AVERAGED FOR OBJECTIVE VERIFICATION

It is therefore difficult to explain why the last case of all should give worse octagon forecasts in the experiment. One possibility is that the SIRS data are of poorer quality in this situation, based as they are on Washington National Meteorological Center (WNMC) *forecast* temperature profiles. If the WNMC forecast was a poor one (as was ours) at the cessation of a blocked situation, then that would be reflected in the quality of the SIRS observations as transmitted. The 48-hour forecast issued by WNMC, based on 00 GMT data for 14 March, has been assessed by CFO as relatively poor near the United Kingdom (compared with the previous and subsequent forecasts). This may be an indication that shorter-period forecasts based on the same data were also relatively poor, in which case the above hypothesis is supported.

Conclusion. Both the objective and subjective assessments of the coarse and fine-mesh forecasts show that in general the inclusion of satellite data in the objective analyses produced small beneficial effects on the forecasts in the region of the British Isles and North Atlantic during the period of the experiment. For the majority (57 per cent) of fine-mesh forecasts, the results were similar or very slightly better when satellite data were included and for about one-third of the forecasts there was a distinct improvement; 43 per cent of the coarse-mesh forecasts showed a distinct improvement. Except for one occasion (00 GMT on 15 March 1974) the inclusion of satellite data did not have any harmful effects, and on that occasion they did not produce any serious errors.

The experiment indicated that the operational use of SIRS data would on the whole be beneficial and would not produce any worsening of the forecasts.

As a result SIRS data were incorporated into the operational objective analysis on 26 March 1974. In view of the larger numbers of SIRS data to be examined by the upper-air forecaster facilities have been introduced for rejecting not only individual SIRS observations but also all SIRS, or all SIRS within particular limits of latitude, longitude and pressure level. The operational use of satellite data showed that they were unsatisfactory in low latitudes, and on 9 April 1974 the octagon analysis was modified to reject automatically all satellite data south of 25°N. It is hoped that continued experience in using SIRS data operationally will lead to improved methods of incorporating them into objective analyses and that in the long term, as their quality improves (as one hopes it will), careful monitoring will ensure that the best use is made of them.

Acknowledgements. We are indebted to numerous Meteorological Office staff for their help in setting up, running and maintaining the experiment, in particular Messrs P. L. Baylis, R. McGain, B. H. Preedy and B. S. Edkins, and CFO roster staff.

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ESTIMATES OF THE PROBABILITY OF OCCURRENCE OF HIGH RATES OF SNOWFALL

By R. N. HARDY

Summary. A method of assessing the likelihood of high rates of snowfall at stations for which lengthy autographic records are available is described, and results are presented for some stations in the United Kingdom.

Introduction. For some design purposes there is a need to specify the probability levels for the occurrence of high snowfall rates. It is not sufficient, even if it were possible, to estimate an all-time extreme value, for the penalties (in weight, cost or efficiency of the equipment being considered) involved in coping with such an unlikely event may be prohibitive.

This note describes an attempt to solve the problem by means of a computer analysis of statistics of hourly rainfall amounts (in tenths of a millimetre) and durations (in tenths of an hour) compiled for several years from autographic rain-gauge records at a number of U.K. stations.

The analysis scheme. Because of difficulties of measurement there is little direct information on rates of snowfall. The Meteorological Office tilting-siphon rain recorder used at main observing stations includes a small heater (25-watt lamp) for frost protection, so that rates of sleet* and slight snow at near freezing point may be measured to a good approximation. However, large rates of fall of frozen precipitation over short periods cannot be determined accurately even by the most skilled and dedicated observer.

The total precipitable water in the atmosphere at a particular place has been found[1] to be highly correlated with the surface dew-point which, when precipitation is falling, is itself closely related to the surface air temperature. This explains why there is a fairly well-defined, although not large, decrease with surface temperature in the proportion of precipitation falling at high rates, except at the temperature extremes which probably mostly correspond to clear anticyclonic conditions. For example, Figure 1 shows a family of histograms for London/Heathrow Airport, each covering all temperature ranges for the 23 years up to 1971. From the left-hand side it gives the percentage time during which the temperature lay within each 2·5-degree Celsius band, the percentage of those times during which rain fell at 0·1 mm/h or more and then percentages of the latter times during which rates of from 2 to 25 mm/h were exceeded. The increasing bias towards high temperatures can be clearly seen. It is possible in view of this to consider rainfall-rate statistics for a temperature band wherein it is known that a large proportion of the precipitation will have fallen as rain, and to argue that this represents an upper envelope for snowfall rates. This is the approach adopted here.

The basic data used comprise rainfall amounts recorded over fixed one-hour periods and the rainfall duration within each hour to the nearest tenth of an hour. Intensities are calculated from these, and the question arises whether or not this masks fluctuations which are sufficient to cause high-intensity rainfall durations to be significantly understated. A good deal of work has been done on relating the variation in duration of rainfall at different rates with the averaging period used. Unfortunately this has primarily been concerned with relating clock-hour averages of convective high-intensity rain with instantaneous (2-minute) intensity distributions (see, for example, Briggs and Harker[2]) whereas the durations used here are resolved to the nearest 6 minutes, and frontal-type precipitation is the main concern. Furthermore, since snowflakes, unlike raindrops, show little change in terminal velocity with size, snowfall cannot be expected to display the same degree of short-period variability as rain. An investigation by Dyer[3] supports this conclusion: she measured the fluctuation of snowfall rates during 15 Montreal snowstorms by using optical instruments operating over a 71-metre path, roughly equivalent to 2½-minute averaging. The rate of fall was found to be essentially a simple Markov process, with a small-amplitude random component superimposed. Power spectra showed a strong low-frequency component, falling off steeply above 4 cycles per hour. It seems reasonable therefore to expect the degree of distortion introduced in the present analysis by the averaging to be small.

Data were considered for 23 locations in the United Kingdom over periods ranging from 6 to 23 years, 376 years in all. Initially frequency distributions

* The term sleet is commonly used in this country to describe precipitation of snow and rain (or drizzle) together, or of snow melting as it falls, but it has no agreed international meaning.

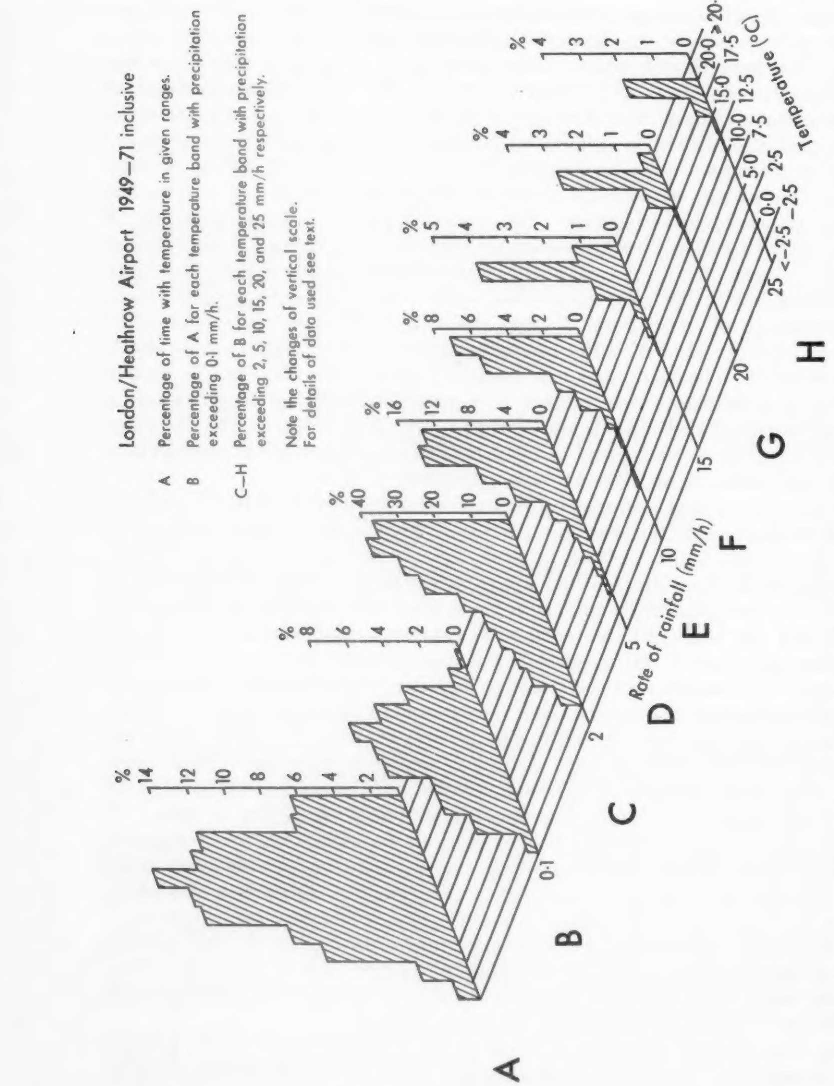

FIGURE 1—AN EXAMPLE TO SHOW THE DECREASE WITH DECREASING TEMPERATURE IN THE PROPORTION OF PRECIPITATION FALLING AT HIGH RATES

of the duration of precipitation at various rates were computed for each 2·5-degC temperature band from −10° to +20°C for each station. The expected decrease with temperature in the proportion of precipitation falling at high rates was evident at all stations. Small amounts of precipitation were reported at temperatures well below 0°C and, although their accuracy as regards rates of fall must be regarded with caution, it was considered that they should be included. It appeared that 2·5°C was a suitable upper temperature threshold, because then a large proportion of the precipitation considered would certainly have fallen as rain, whilst most sleet, almost all snow and a little hail would also be included. Hence percentages of precipitation exceeding various rates with air temperature less than 2·5°C were computed for each station. The few periods of precipitation at very high rates were individually checked against the reported weather, and cases of ice pellets or graupel were excluded. This is because the processes of formation differ from those of snow so that the two are in no sense interchangeable. To be fully consistent, rain from convective cloud should also have been excluded, but because such a very small part of precipitation at temperatures below 2·5°C falls as rain showers such refinement is not essential.

Results. The cumulative percentages for each station were plotted on logarithmic graph paper and straight lines fitted by eye. In all cases the fit was quite good—indeed the three largest departures were found to be data errors when checked against the original records; examples are given in Figure 2 for London (Heathrow), Edinburgh (Turnhouse), Cardiff (Rhoose), Belfast (Aldergrove) and Lerwick. From the set of curves, rates of precipitation exceeded for 1 per cent and 0·1 per cent of the time were read off. These values are listed in Table I and plotted in Figure 3; they are considered to represent realistic if slightly exaggerated estimates of rates of snowfall likely to be encountered within the lowest few hundreds of feet, for the given percentages of the time that the surface temperature is below 2·5°C and precipitation is falling at a rate of 0·1 mm/h or more. The isopleths in Figure 3 must be regarded as largely speculative, though the broad minimum over central England, coastal maxima and local maximum south-east of the Cheshire gap do not appear unreasonable.

If it is required to estimate the likely frequency of encounter with snowfall at these rates, then each must be associated with a duration. The basic data have a minimum resolvable period of 6 minutes; consideration of the duration of falls exceeding 4 mm/h within clock hours suggests that they may be associated with periods averaging about 30 minutes (over the United Kingdom). In other words, in the course of 500 hours of precipitation at temperatures below 2·5°C, one might expect 10 independent 30-minute falls at the 1 per cent rate, one of which would reach the 0·1 per cent rate.

If overall probabilities are required, it is necessary to know the proportion of time during which precipitation falls on average when the temperature is below 2·5°C—factor A, and the proportion of total time during which the temperature is less than 2·5°C—factor B. These factors in percentage form are given in Table I for the 23 U.K. locations analysed and plotted in Figure 4.

TABLE I—RATES OF PRECIPITATION EXCEEDED FOR 1 PER CENT AND 0·1 PER CENT OF THE TIME DURING WHICH THE SURFACE TEMPERATURE WAS BELOW 2·5°C AND PRECIPITATION WAS FALLING AT 1 mm/h OR MORE; PERCENTAGE OF TIME DURING WHICH THE TEMPERATURE WAS BELOW 2·5°C AND PERCENTAGE OF THAT TIME WITH PRECIPITATION FALLING AT 0·1 mm/h OR MORE (DATA FOR 23 STATIONS IN THE UNITED KINGDOM)

Station	Height above mean sea level (*metres*)	Period of data (inclusive)	Rate of precipitation (mm/h) exceeded for 1%*	0·1%*	Percentages of time A	B
Aberporth	133	1957–71	4·0	6·0	4·95	6·83
Belfast (Aldergrove)	68	1949–71	4·7	7·0	7·05	11·69
Birmingham (Elmdon)	96	June 1949–71	3·7	5·5	5·55	14·52
Boscombe Down	126	1957–71	3·6	5·4	4·10	13·50
Cardiff (Rhoose)	67	1957–71	3·4	5·1	4·69	10·07
Dishforth Leeming	32 32	1957–Sept. 1965 Oct. 1965–71	3·6	5·3	10·27	14·82
Edinburgh (Turnhouse)	33	1957–71	3·8	5·6	4·80	15·00
Eskdalemuir	241	1957–70	4·2	6·1	9·62	23·13
Glasgow (Renfrew) Glasgow (Abbotsinch)	8 5	1949–Apr. 1966 May 1966–71	4·2	6·2	5·45	13·08
Kew	5	1957–69	3·2	4·7	4·23	9·29
Kinloss	113	1959–71	4·6	7·0	12·56	14·82
Lerwick	82	1957–70	4·8	7·1	12·22	15·31
London (Heathrow)	25	1949–71	3·5	5·2	3·72	11·42
Manchester (Ringway)	75	1949–71	3·4	5·0	5·17	12·63
Manston	44	1961–71	4·1	6·2	5·80	9·95
Mildenhall	5	1949–Sept. 1969	3·2	5·0	4·07	13·84
Plymouth (Mount Batten)	26	1949–61	4·5	6·6	2·94	5·01
Prestwick	16	1957–71	4·1	6·1	4·57	12·00
Stornoway	3	1957–71	5·0	7·2	8·15	10·18
Thorney Island	4	Aug. 1958–71	4·0	5·9	3·17	9·66
Tiree	9	1957–71	4·9	7·0	5·20	4·65
Valley	10	1957–71	4·1	6·0	4·24	5·73
Wick	36	1957–71	4·8	7·1	9·64	12·83

* These percentages refer to the period with temperature below 2·5°C and precipitation falling at a rate equalling or exceeding 0·1 mm/h.

A For temperatures below 2·5°C, the percentage of time during which precipitation fell at a rate of 0·1 mm/h or more.

B Percentage of time during which the temperature was below 2·5°C.

It is emphasized that the isopleths drawn in Figure 4 must be regarded as highly smoothed estimates since local factors, especially station altitude, play such a large part. As an example consider Stornoway:

(a) From Table I—given an air temperature below 2·5°C and snow, we could expect an equivalent rainfall rate of 5·0 mm/h for 1 per cent and 7·2 mm/h for 0·1 per cent of the time.

(b) Using Factor A and the above—given a temperature below 2·5°C we could expect snow at an equivalent rainfall rate of 5·0 mm/h for less than 0·082 per cent and at 7·2 mm/h for less than 0·0082 per cent of the time. The 'less than' must be included because some occasions will be of rain and some of sleet at ground level.

(c) Over the year as a whole we should expect snow at the above rates for less than 0·0083 and 0·00083 per cent of the time (factors A and B), or about 1 hour in 10 000 and 1 hour in 100 000 respectively.

From Figures 3 and 4 it is possible to assess probabilities of heavy rates of snowfall for any location in the United Kingdom.

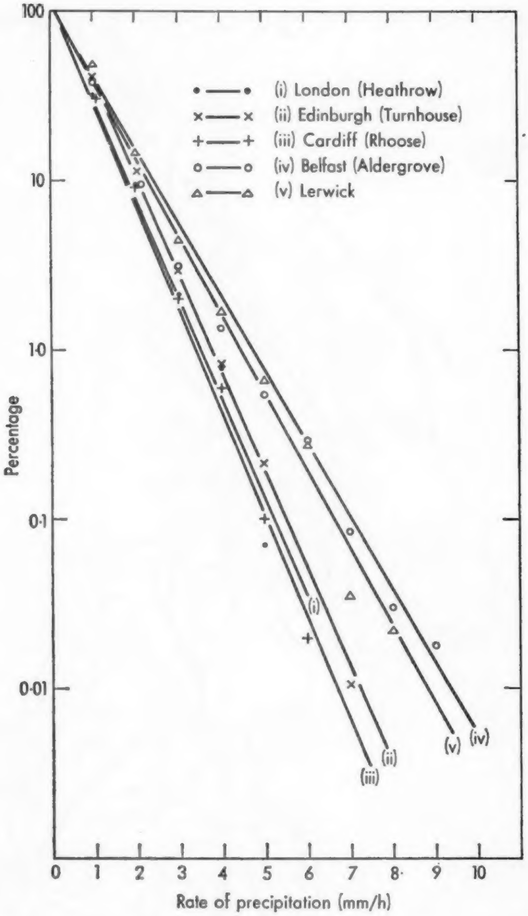

FIGURE 2—PERCENTAGE OF PRECIPITATION EXCEEDING GIVEN RATES AT TEMPERATURES BELOW 2·5°C AT FIVE STATIONS

Discussion. The assumptions, explicit and implicit, in the foregoing analysis have already been mentioned; this section will be concerned with tentatively relating the results to world-wide conditions, and taking into account topography and altitude.

An extension to world-wide conditions. There is no reason to associate heavy rates of snowfall with high latitudes. On the contrary, areas where very cold air occasionally crosses relatively warm stretches of water are subject to the heaviest falls. The United Kingdom is more suitably situated for such falls

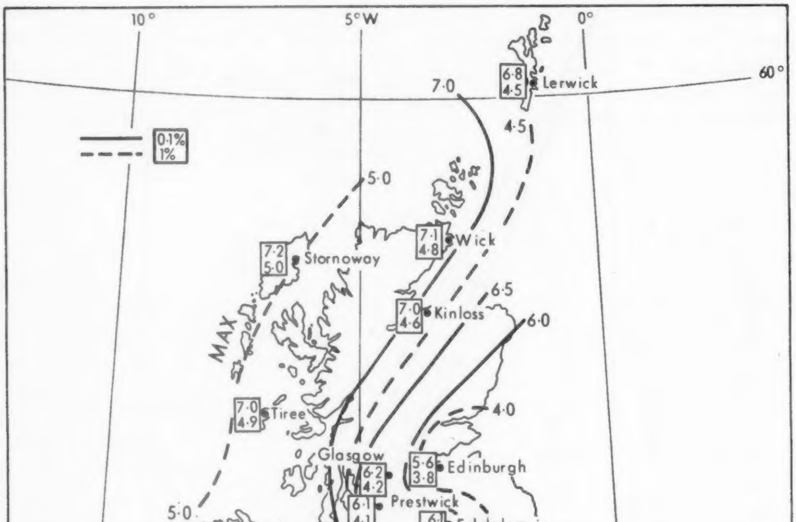

FIGURE 3—RATES OF SNOWFALL EXPRESSED AS WATER EQUIVALENTS IN MILLIMETRES PER HOUR WHICH ARE LIKELY TO BE REACHED FOR 1 % AND 0·1 % OF THE TIME DURING WHICH SNOW FALLS AT A RATE EQUALLING OR EXCEEDING 0·1 mm/h

than most countries, though parts of Japan, the southern Alps, and areas bordering the Great Lakes of North America and the Caspian Sea can be expected to suffer more prolonged heavy snow under favourable circumstances. Not surprisingly data are sparse. The world record snowfall, discussed by Paulhus,[4] of 76 inches in 24 hours at Silver Lake, Colorado (10 220 ft above mean sea level) averages out at about 7·2 mm/h water equivalent; this suggests

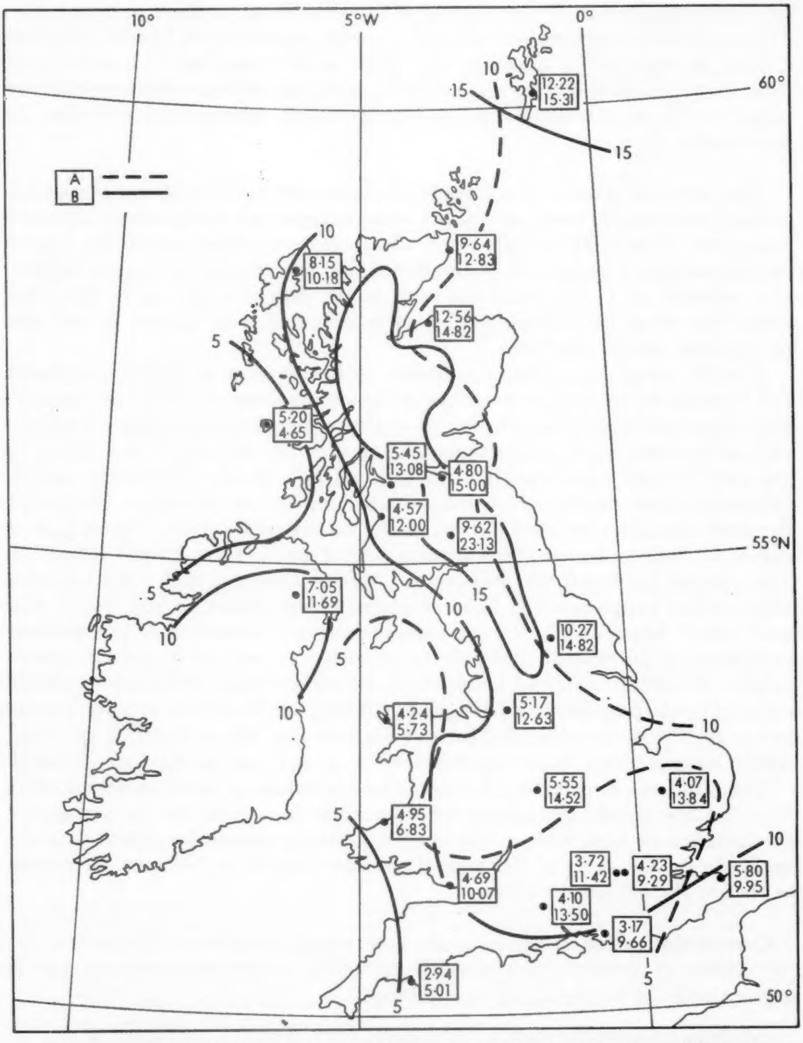

FIGURE 4—PERCENTAGE OF TIME WITH TEMPERATURE BELOW 2·5°C DURING WHICH PRECIPITATION FELL AT 0·1 mm/h OR MORE (A) AND PERCENTAGE OF TIME DURING WHICH TEMPERATURE WAS BELOW 2·5°C (B)

that extreme falls may amount to exceptional durations of heavy snow, rather than exceptionally heavy rates of snowfall. Much has been written about the heavy snowstorms which affect regions bordering the Great Lakes of North America; most aspects are covered in a recent study carried out at the State University of New York.[5,6] Invariably these storms are associated with large temperature differences between airstream and water of up to 15 degC, and

produce considerable depths of snow of very low density, down to 0·02 g/cm^3. The probabilities derived here for high snowfall rates over the United Kingdom cannot be expected to apply to the Great Lakes area, but it is considered that, when modified for the appropriate percentage of time with temperatures below 2·5°C, they will provide realistic if slightly exaggerated estimates for most parts.

Topography and altitude. It is necessary to distinguish between these factors: high ground, particularly windward slopes, must be expected to experience a greater proportion of snowfall at high rates, whilst above uniform terrain the rate of precipitation in a non-showery situation would be expected to increase slightly with altitude up to the cloud base (or, in the case of snow, up to that level below the cloud base at which the air is saturated with respect to ice) and to decrease above this level.

A crude assessment of the probability of heavy snow at different altitudes can be made by assuming a mean temperature lapse rate of 2 degC per 1000 ft* and using a modified B factor. For example, we may regard a surface temperature of less than 2·5°C as corresponding to snow in the lowest 1250 ft, 2·5 to 5·0 degC to the 1250–2500-ft altitude band and so on. The mean annual percentage time during which the surface temperature lies below the chosen threshold can then be used instead of the tabulated B factor; Figure 5 gives curves for four locations which represent most areas of the United Kingdom. The amount by which the proportion of precipitation at high rates increases with surface temperature is to some extent compensated by the loss of that part which forms below the altitude of interest; nevertheless, probabilities calculated in this way should only be regarded as order-of-magnitude assessments. If interest is strictly confined to the surface then probabilities can be reduced by the proportion of precipitation falling as rain or sleet at temperatures below 2·5°C. An analysis by Murray[7] suggests that this is about 60 per cent, whilst more recently Auer[8] reported it to be 50 per cent in the United States.

The problem of correcting for mountainous terrain is rather different. Perhaps the best simple adjustment where possible is to scale the percentages of precipitation at high rates at the nearest low-level station for which data are available by the ratio of the annual average rainfall in the area of interest to that at the low-level station.

Conclusion. The data presented enable rough estimates to be made of the probability of occurrence of snowfall exceeding a selected threshold rate in a given area. The procedure is as follows:

(a) Select a suitable station (or region) from Table I or Figure 3.

(b) Use 1·0 and 0·1 percentage values to draw a straight-line curve on semi-logarithmic paper as in Figure 2.

(c) Read off the percentage against the required rate.

(d) Modify as required, using the factors in Figure 4 and an altitude correction if necessary. In particular, reduce by 60 per cent if interest is strictly confined to ground level.

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* This corresponds approximately to the saturated adiabatic lapse rate for near 0°C between 1000 and 800 mb.

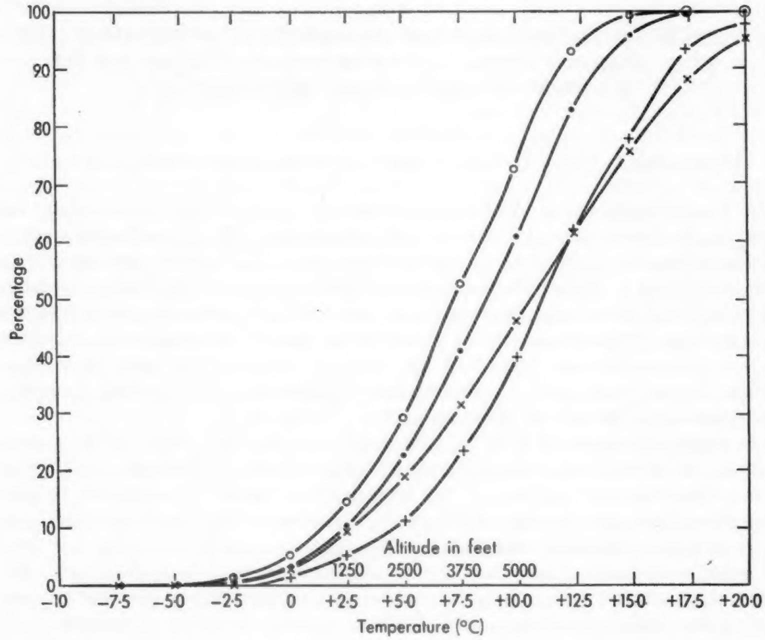

FIGURE 5—PERCENTAGE OF TIME DURING WHICH THE SURFACE TEMPERATURE IS BELOW GIVEN VALUES AT FOUR STATIONS

×——× Kew
●——● Stornoway
○——○ Lerwick
+——+ Plymouth

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WORLD METEOROLOGICAL ORGANIZATION COMMISSION FOR AGRICULTURAL METEOROLOGY (CAgM) SIXTH SESSION—WASHINGTON, OCTOBER 1974

By C. V. SMITH

(Meteorological Office, Ministry of Agriculture, Fisheries and Food, Cambridge)

The Sixth Session of the WMO Commission for Agricultural Meteorology was held in the International Conference Room of the U.S. State Department in Washington, D.C., from 14 to 25 October 1974. The session was opened by the Hon. Earl L. Butz, U.S. Secretary of Agriculture, and Mr Taha, President of WMO and Dr Davies, Secretary-General of WMO, spoke to the conference on the 21st. Representatives of 55 countries and of non-governmental international organizations, including the United Nations Food and Agriculture Organization, took part in the plenary conference; the United Kingdom delegates were Messrs R. Murray and C. V. Smith.

It might be supposed that, in a turbulent world, the march of the seasons and the patterns of agriculture would at least provide evidence of a changeless scene, and that one meeting of the Commission would be much like its predecessors. Not so. In only three years, the concern in some countries over food surpluses has been transformed by a general concern over the low level of world food reserves and the threat and appearances of food shortages. The general awareness, even among lay people, of the possibility of climatic change, and of the profound consequences of season-to-season weather variations in the marginally productive lands of parts of Africa and Asia, has led to studies of the role of the weather in the seasonal variability of crop yields in some of the main grain-producing areas of the world. The residual variance due to weather takes on greater importance as the upward trend in yields, arising from advances in technology over the past 30 years, begins to flatten out, whilst population projections continue upwards. All these developments, which have taken place during the past few years, have dictated the changes in the role and direction of effort of the Commission for Agricultural Meteorology.

In its early days, the Commission acted as a forum for the exchange of information and techniques, and for authoritative reviews of the present position of agrometeorological activities. This important work obviously still goes ahead, but the appearance of operational Working Groups is a new and far-reaching departure from the past. The new or reconstituted groups, for example, on International Experiments for the Acquisition of Crop Weather Data (wheat and lucerne), deliberately set out to generate new information; from closely monitored field experiments, the phenological, field and weather data necessary to derive quantitative relationships (models) of crop growth and yield are being actively sought. Further emphasis on this operational aspect of the Commission's work was given by the establishment of a Working Group on Weather and Climate as related to World Food Production, charged, among other things, with a study of the expanded procedures necessary to the World Weather Watch data-collection system, which would provide real-time data to enable up-to-date areal assessments of crop performance, and, it was to be hoped, some forewarning of where, and by how much, surpluses and deficiencies in yields would arise. Further groundwork for this effort was laid by the

appointment of a Rapporteur on Mathematical Simulation Modelling in Agrometeorology and the decision to hold a symposium on techniques in crop-weather analysis.

The Working Group on Weather and Animal Diseases was re-established and is again composed of people who place their emphasis on action rather than on review, and who see their purpose as that of initiating and developing warning and forecasting systems for those weather-sensitive diseases about which something is known already, and to undertake more speculative studies on the role of weather in some parasitic diseases and in mycotoxicoses. The impact of weather and environment on intensive livestock production had been well covered by U.K. contributions in the past. Further requirements (until the next session) might, it was decided, be adequately met by a symposium on animal husbandry, which would now take into consideration the management of extensive grasslands and those resources that can only be adequately exploited by use of livestock.

The view of the Commission on the need for action and application, rather than for words, was elaborated in the Recommendation to Member Countries to develop extended forecasts for agriculture. The terms of reference of the Rapporteur appointed on this topic direct attention to many areas such as water usage and requirements, field-work days of all kinds, and warnings on pests and diseases, etc. for which the basis for advice already exists in this country. These involve some elaborate manipulation of weather parameters and, though a great many U.K. farmers possess the technical competence to carry it out, the necessary data cannot be derived from general weather forecasts. The implications of current weather and weather forecasts, for agriculture, could and should be examined more than they are at present. Certainly many countries take the view that such help should be provided, and Dr Landsberg, President of the Commission for Special Applications of Meteorology and Climatology (CoSAMC), in his cogent arguments for such a service, was in no doubt of the need for, the farmer's response to, and the financial return from, such a service.

It is indeed necessary to emphasize the practical economic value of agrometeorological services; so long as there are limited financial resources, there is the need for concrete examples to highlight the benefit/cost ratio of agrometeorological services. Again a Rapporteur was appointed for this purpose.

Any meeting of the Commission (generally at intervals of four years) has three main tasks:

(a) to review progress and technical work since the previous meeting;
(b) to identify and analyse global agricultural problems related to weather and climate; and
(c) to propose a further programme of research, training and operational services.

Work under (a) above at Washington was rather restricted by the absence of many completed reports; these were mostly available to the Secretariat but, in marked contrast to previous sessions, were not all distributed before the meeting. The availability of single copies for inspection in the conference chamber did little to relieve an air of unreality in some of the discussions until they moved on to the items listed in (b) and (c) above. This is perhaps the point at which to mention that the report by J. W. Davies (Meteorological Office) on the Meteorological Effects of Soil Cover has been approved for

publication as a WMO *Technical Note*. Other U.K. contributions found their place in reports on Weather and Animal Disease and in collected papers on soil erosion.

The analysis of problems and of key areas for future work can be subdivided into the following broad fields: methodology; meteorological factors affecting soils and crops, and plant injury, pests and disease; meteorological factors affecting animal production, and animal pests and disease; economics; and training. The subject matters that hold a challenge for the United Kingdom have already been outlined in the early part of this article, but among the topics for the many Working Groups and Rapporteurs appointed at CAgM-VI, we find many where U.K. expertise would, of necessity, be limited to problem solving as distinct from field experience. These include work on rice, the epidemiology of the cassava mite, forestry, water use and land-use management under severe climatic conditions, etc. Essentially the demand for such work represents a call for help by the developing countries; commonly this call for help has taken the form of requests for expanded observational networks and manpower training, a procedure which obscures the underlying necessity for aid in achieving some basic understanding of agrometeorological problems, for aid in identifying key areas for work, and for aid in translating understanding into application and operating systems. The problems for both developing and more advanced countries are thus seen to be closely related and often complementary. The small number of agrometeorologists in the United Kingdom, for example, is not enough to support a training programme; the more difficult problems are not necessarily technical but are related to organizational renewal, development and change.

There is little doubt that the discussions at the 6th Session of CAgM were always harmonious and often fruitful although sometimes rather lengthy. However, the success of any meeting is not easily assessed. Many delegates must surely have returned to their own countries having gained something of personal value from friendly contact with colleagues from widely scattered parts of the world. However, the more tangible success of the meeting in Washington will probably be measured by the quality of the technical reports expected to emerge in the next four years from the nine Working Groups and 14 Rapporteurs appointed by the Commission.

REVIEW

Atmospheric waves, by T. Beer. 255 mm × 195 mm, pp. xvi + 300, *illus.*, Adam Hilger Ltd, 29 King Street, London WC2 E8JH, 1974. Price: £16.

There is no doubt that the subject of atmospheric waves is complex and much of the literature is difficult for the more casual reader to comprehend. For this reason a book carefully presenting the essential characteristics of the different classes of waves which occur in the atmosphere would have been most welcome. The author states that he has intended this book for both novices and experts in atmospheric physics and other workers in earth sciences. However, the book not only fails to meet the requirements of either group but owing to its muddled, incomplete, and occasionally erroneous treatment of the subject, it cannot be recommended. In such a complex subject the failure to meet the requirement of both groups might be regarded as inevitable, but the very poor standard of the material is made especially disappointing by the useful references to excellent review books and papers.

The book has chapters inaccurately entitled 'The theory of atmospheric waves; Waves in real atmospheres; Waves in the lower atmosphere; Atmospheric tides; Waves in the ionosphere; Non-linear effects'. The material covered not only includes the sound, internal gravity, Rossby, and other types of waves expected but also digressions on subjects such as computational stability and turbulence. The author's own field of work concerns waves in the upper atmosphere and it is this part of the material which is dealt with in the most detail. Whilst the treatment of this area is reasonably accurate, its value is lost in its muddled presentation and links with the thoroughly inadequate treatment of waves in the lower atmosphere.

Inaccuracies vary between mathematical ones, such as an erroneous definition of dispersion, and a statement that the Coriolis and centrifugal forces may be incorporated into the geopotential altitude, and interpretative ones which are contradicted by the references given to support them. The assertion that atmospheric long waves are Rossby waves and 'free' when they arise 'from baroclinic, barotropic, and thermal forcing' or 'forced' when 'due to mountains and continents' whilst cyclone waves are due to barotropic instability of meridional shear is certain to confuse readers. The section on turbulence is especially grim and concludes with the suitably erroneous statement that the low-wave-number planetary waves produced by mountains and continents have a k^{-3} spectral distribution. The mathematically dubious treatment of baroclinic instability is the case with zero static stability (in spite of references to Eady and other work which crucially contains a static stability) and naturally produces only a long-wave cut-off. The short-wave cut-off, which a static stability is crucial in creating, is attributed to the 'effect of vertical motions on the meridional temperature gradient'. We are told that when the Rossby number of a mountain is less than about 0·5 the column of air above it is stagnant in a 'Taylor column'. There is no such Rossby-number criterion for the occurrence of a Taylor column and his statement leads to the erroneous conclusion that such 'Taylor columns' occur frequently in the atmosphere. The book contains many other serious errors, and it is surprising that the publishers awarded this disappointing and expensive book the 'Adam Hilger Prize'.

P. J. MASON

LETTER TO THE EDITOR

An objective aid for estimating the night minimum temperature of a concrete road surface

A minor error has been noticed in the above-named paper (THORNES, J. E.; *Met Mag, London*, **101**, 1972, pp. 13–25). On page 18, section (c), it is stated that Swinbank's formula for estimating outgoing radiation, E, is

$$E = 5{\cdot}31 \times 10^{-14}\, T^6 \text{ mW/cm}^2.$$

In fact this is Swinbank's formula for incoming long-wave radiation from clear skies, R, and

$$E = \sigma T^4 - R \text{ mW/cm}^2$$
$$= (\sigma T^4 - R) \times 1{\cdot}4335 \times 10^{-2} \text{ cal/(cm}^2\text{ min)},$$

where σ = Stefan's constant, for which Swinbank used the value $5{\cdot}77 \times 10^{-9}$ mW/cm² K⁻⁴.

The point only occurs in an outline of a possibility, which was not pursued, of removing a variable from the argument. It does not affect the basic method presented in the paper.

Meteorological Office,
Bracknell.

C. L. HAWSON

AWARDS

ROYAL METEOROLOGICAL SOCIETY AWARD TO THE DIRECTOR-GENERAL

The Royal Meteorological Society has awarded its Symons Memorial Gold Medal to the Director-General of the Meteorological Office, Dr B. J. Mason, C.B., F.R.S. The citation reads as follows:

The Symons Memorial Gold Medal for 1975 is awarded to Dr B. J. Mason for his outstanding contributions to the development of the science of meteorology, and, in particular, for his contributions to the understanding of the physics of clouds. Not only has Dr Mason carried out numerous fundamental studies of cloud microphysics and electrification, and produced in his 'Physics of clouds' the definitive work on the subject, but he has, as Professor of Cloud Physics at Imperial College from 1961 to 1965 and subsequently, exerted a major and much needed influence on the study of cloud physics which has assured its development on a sound scientific basis.

As Director-General of the Meteorological Office since 1965, he has, by his outstanding scientific leadership and encouragement, fostered major developments over a very wide range of meteorology both in the United Kingdom and abroad. These include development of numerical weather prediction and computer study of climate and climatic changes as well as such international experiments as the Atlantic Tropical Experiment (GATE) of the Global Atmospheric Research Programme for which he undertook onerous responsibilities as chairman of the Tropical Experiment Board. The sound but rapid developments of stratospheric physics both nationally and internationally in an age of new technologies owe much to his efforts.

AWARD OF IMO PRIZE TO DR JOSEPH SMAGORINSKY

We note with pleasure that the nineteenth International Meteorological Organization Prize for outstanding work in meteorology and in international collaboration has been awarded to Dr Joseph Smagorinsky, Director of the Geophysical Fluid Dynamics Laboratory of the United States National Oceanic and Atmospheric Administration.

CORRECTIONS

Meteorological Magazine, January 1975, p. 23, caption to Figure 5, last line: for 'From Figures 2 and 4' read 'From Figures 3 and 4'.

Meteorological Magazine, March 1975, p. 83, Table VI. In the column headed S, the entry opposite 'September' should be '$0{\cdot}44\ G + 0{\cdot}20$'. On page 84, Figure 1, the y-axis for the October graph should be numbered from 0 to 4 and not from -1 to 4.

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NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, and marked 'For Meteorological Magazine'.

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

Printed in England by Heffers Printers Ltd, Cambridge
and published by
HER MAJESTY'S STATIONERY OFFICE

28p monthly **Annual subscription £3.78 including postage**

Dd. 289060 K16 5/75 ISBN 0 11 723072 3